

NEXT GENERATION'S ENERGY AND TIME EFFICIENT NOVEL PRESSURE COOKER

SUNIL G. SHINGADE¹ & PRASHANT D. GANGAWANE^{2*}

¹Insightbitz Products and Services Private Limited, Mumbai, Maharashtra, India

²Professor, Department of Textiles, D.K.T.E.Society's Textile and Engineering Institute, Ichalkaranji, Dist.: Kolhapur,
Maharashtra, India

ABSTRACT

Cooking is a basic need in day to day life which makes it the world's most energy consuming sector among all others utilizing 30% of the total energy consumption of the world. Cooking is a physicochemical process and it requires thermal energy. Therefore it is need of the hour to make the cooking practices more thermal efficient.

In this research work, a novel heat transfer phenomenon occurring while the cooking process is in progress was observed and on the basis of the observed phenomenon designing principles of energy and time efficient cooking device has been proposed. Till the present time, it was considered that in cooking phenomenon, as the heat gets supplied externally to the cooking device, the temperature increases and eventually cooking goes in progress. But in this newly invented cooking device, this phenomenon of cooking is distinctly different in which temperature inside the cooking vessels rises even after terminating the fuel supply. It is also observed that, as the heating is in progress and once the temperature of water reached up to 85°C for rice and 95°C for lentils then there is no need for further heat supply and sensible heat content inside the water is sufficient for carrying out further cooking process completely. The mechanism of heat transfer and fluid mechanics occurring inside the cooking volume in this innovative cooking device is completely different from the existing cooking devices. In this novel cooking device, cooking gets initiated from the top of the layer and proceeds towards the bottom layer. Water required for carrying out the cooking gets trickle down from the top layer to the bottom layer. The science accountable for this naturally occurring phenomenon of heat transfer and fluid mechanics has been taken into the consideration for the development of this novel technology and cooking device accelerates the cooking process with 70 to 80% saving of energy.

This Next generation's energy and time efficient novel pressure cooker can solve two major environmental and economical problems: limitation of environmental pollution due to the burning of additional fuels and reduction of the fuel costs since the process requires relatively low consumption.

KEYWORDS: Heat Transfer Phenomenon, Pressure Cooker, Energy, Time, Cooking Device, Lentil, Rice, Fuels & Environmental Pollution

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INTRODUCTION

30% of the total energy consumption of developing countries is utilized in the cooking sector only ¹. 31% of the total energy consumed in the cooking sector comes from commercial fuels such as gas Kerosene or coal and the remaining 69% comes from firewood and agricultural waste ². Cooking is a physicochemical process and it requires energy. Therefore it is necessary to apply energy conservative strategies to the cooking practices. Conventional en-

ergy sources like kerosene, gas, and coal are depleting steadily ³. Non-commercial sources like agricultural waste, firewood, etc. are not economically viable. Therefore it is need of the hour to utilize conventional energy sources efficiently and effectively.

There are several cooking methodologies that exist in current practices. Open pan cooking system is one of them which widely get used. 75% population of developing countries resides in rural areas, whereas open pan cooking methodology is still in practice ⁴. Open pan cooking system is considered as conventional cooking methodologies which consist of a vessel containing the mixture of food grains and water, placed on the flame directly and expose to the atmosphere. It usually contains a lot of excess quantity of water rather than required. It is known that rice during cooking typically absorbs two to three times of water of its own weight ⁵. This ratio in an open pot cooking system is nearly about 1:5. This excess quantity of water is then drained off and heat losses take place in the form of sensible heat content. In an open pan cooking system, vaporization of water takes place continuously and heat losses take place in the form of latent heat content. Steaming is also one of the popular arts of cooking with direct or indirect contact. A direct contact steam cooker consists of multiple vessels placed one upon another. The bottommost vessel contains water while the uppermost vessel, contains food grains to be cooked. These vessels are equipped with central pipes to carry the steam inside of each vessel. Some of the vessels have a perforated bottom to pass the steam inside the food material. As the steam enters inside the vessels, then cooking takes place by absorbing the entered steam. The limitation of such type of cooking art is associated with the loss of steam to the surrounding, as it operates at atmospheric pressure. Indirect steam cookers are also used in current practices. It consists of a series of vessels containing the mixture of food material and water and placed one upon another. These vessels are enclosed by a steaming chamber in which water is taken inside the base of the steaming chamber and it is placed on the flame directly. As the heating is in progress, steam gets to form and condenses on the outer wall of vessels and further transfers latent heat to the vessel contents. The limitation with such types of cookers is that steam gets loss to the surroundings continuously as it operates at atmospheric pressure and therefore thermal efficiency goes down. A pressure cooker is also one of the indirect type of steam cookers which operates on the principle of boiling point elevation of water. However, because of the safety issues, its size is limited to a cooking volume of 10 to 20 liters. Pressurized cooking practices are more efficient than open pan cooking and have thermal efficiency in the range of 30 to 40% ⁶.

The temperature profile inside the cooking mass gets changes continuously while the cooking process is in progress. Therefore it is necessary to understand the basic heat transfer mechanism occurring inside the cooking mass before going to apply energy conservative strategies to cooking practices while the cooking is in progress.

Cooking is an essential need in day to day life and one of the largest energy consuming sectors among all others. 30% of energy consumption of the world is going to utilize for cooking purposes only. The fuel that is used for cooking purposes in developed countries is mainly electricity and it is considered a clean source of fuel. However, coal is going to use as a fuel in electricity generation plants and has an efficiency of about 30%. It leads to the production of a huge amount of carbon dioxide and carbon monoxide due to partial combustion and finally affects the climate. But in developing countries, liquefied petroleum gas (LPG) or piped natural gas (PNG) are going to use as a fuel for cooking purposes in current cooking practices. The burning of such fossil fuels produces a large amount of carbon dioxide in confined space. Therefore, the concentration of carbon dioxide in the confined space increases and affects the climate and health of the people working in the vicinity. Therefore it is necessary to apply energy conservative strategies to cooking practices so that cooking can be carried out with less amount of fuel consumption in order to reduce the production of carbon dioxide drastically.

Therefore, it gives a significant positive impact on energy saving as well as prevents climate from getting polluted to high intensity.

Effect of Carbon Dioxide on the Climate

Carbon dioxide is going to release into the environment by burning fossil fuels. This released carbon dioxide absorbs solar energy and keeps it to the earth's surface rather than releasing it to the environment. That trapped heat by carbon dioxide is known as the green house effect. Green house concept came into the picture in the 19th century. In 1824, French mathematician Joseph Fourier predicted that the earth would be much colder if it had no atmosphere. In history, Swedish scientist Svante Arrhenius first correlated the effect of carbon dioxide on warming effect⁹.

Effect of Carbon Dioxide on Human Health

Carbon dioxide can have a negative impact on human health also. It can create a variety of health related problems like difficulty in breathing, increased heart rate, elevated blood pressure and feeling of tiredness etc. The rate of carbon dioxide released through the combustion of fuels generally used in cooking practices has been estimated and its effects on the health of human beings have been briefly discussed. The theme of this research work is to accelerate the cooking process with minimum fuel consumption so that fuel saving takes place and it gives a positive impact on the economy of the cooking industries. As the cooking process gets accelerate with minimum fuel consumption then the cooking time gets reduced and the build-up concentration of carbon dioxide in confined spaces of kitchens can be reduced drastically and exposure time of human beings to the released carbon dioxide can also be decreased.

Experimental Procedure

Experimental set-up of an indirect steam cooker for carrying out cooking at one atmospheric pressure has been shown in figure 1. It consists of a steaming chamber and a set of three cooking vessels placed one upon another. These all three vessels are enclosed by a steaming chamber. The steaming chamber consists of a basal receptacle and hollow air cylindrical jacket. As heating was in progress, water is taken into the base of the basal receptacle boiled and steam gets generated. Generated steam traveled upwards and condensed on the outer wall of vessels and transferred latent heat to the vessel contents. Therefore it is called an indirect steam cooker. Each vessel consists of 3 kg of rice and 2.5 times of water, since during cooking rice absorbs 2 to 3 times of water of its own weight. Temperature sensors were located at 25 mm and 50 mm from the bottom of each vessel as shown in figure 1. The LPG gas was used as a fuel and it was supplied at the rate of 16 grams per minute. The resulting temperature profile has been noted down and on its basis, novel heat transfer mechanism occurring inside the cooking process has been proposed. On the basis of the proposed mechanism of heat transfer, energy and time efficient cooking device was designed, fabricated, and validated experimentally.

RESULTS AND DISCUSSIONS

Observed novel Phenomena of Heat Transfer Occurring inside the Cooking Vessel

The cooking vessel of an indirect steam cooker containing the mixture of food grains and water has been shown in figure 2. It consists of two portions which are described as portion1 & portion 2 in figure 2. Portion 1 contains free water only, while portion 2 contains a bed of rice particles along with water insides of its voids. The heat transfer mechanism depends upon the state of food material inside the vessels. If only water exists, then the heat transfer mechanism gets controlled by convection, but in the presence of food grains, the mechanism is much more complicated and it is necessary to understand

it thoroughly. The experiment has been performed for understanding the heat transfer mechanism occurring while the cooking processes are in progress. Maximum temperature of steam to be achieved in non-pressurized cooking device is 100 °C as the boiling point of water at one atmospheric pressure is 100°C. In such types of cookers if the rate of heat supply is lower then, heating and cooking take place simultaneously. As the cooking proceeds, gelatisation of starch takes place and these gelatised masses get adhered to each other so that the heat transfer process gets controlled partially by conduction and partially by convection. As the heat supply rate is on higher side means the rate of rising temperature is much higher than the rate of cooking. In such a case it is necessary to understand the heat transfer mechanism occurring in the cooking process. The LPG gas was used as a fuel and it was supplied at the rate of 16 gm/min. The resulting temperature mapping has been given in table 1 and the temperature profile has been shown graphically in figure 3. The rate of fuel supply is such that, the temperature of water content inside the vessels reaches more than 95 °C before the marginal cooking takes place. From these observations, it is clear that, fuel supply was terminated at 25 minutes and even after terminating the fuel supply, the local temperature inside the vessels rises. The scientific reasoning behind this magical phenomenon has been elaborated as follow:

As portion 2 contains water inside the voids of the bed of food grains, and the rate of rising temperature in this portion is lower than that of free water present in portion 1. This is due to the difference in availability of the heat transfer area and controlling mechanism of the heat transfer process. Here entire wall surface area of portion 1 is going to utilize to transfer heat to the water content, while the wall surface area of portion 2 is partly occupied by water and partly occupied by food grains. Therefore wall surface area of portion 2 is not going to utilize entirely for heat transfer. Therefore the rate of heat transfer in portion 1 is higher than that of portion 2. Therefore the temperature of free water residing above the bed of food grains rises earlier than that of the water trapped inside the voids of bed. The second scientific reason, behind the observed supernatural phenomena of heat transfer, is that the heat transfer process taking place in portion 1 is completely controlled through convective mechanism, because of the presence of free water only. However, the convective currents going to develop inside the portion 2 gets disturbed due to the presence of food grains. Therefore the rate of heat transfer taking place in portion 2 is lower than that of portion 1. Therefore, the water residing above the bed of the food grains is going to heat up earlier than the water trapped inside the voids of bed. It is known that, as the temperature of water increases, its density decreases. Therefore, low temperature water having higher density resides on the bottom side, while high temperature water having lower density resides on upper side. Therefore, there is a vertical temperature variation inside the vessel. As the temperature inside the bed reaches its minimum cooking value then cooking gets initiated. It is known that minimum cooking temperature for rice is about 74°C and that of lentils is about 94°C⁷. As cooking gets initiated, grains start to absorb water inside it and bed gets expand in the upward direction and at the same time, relatively high temperature water gets to flow in the downward direction and takes the place of absorbed water. Downward flowing water is at a relatively higher temperature and therefore local temperature inside the vessels rises as the cooking is in progress even after terminating the fuel supply. This scientific phenomenon clearly indicates that, if the cooking process is in progress and the temperature of vessel contents reaches more than 85°C in the case of rice and 95 °C in the case of dal (lentils) then the cooking proceeds in its own heat even after terminating the fuel supply. Fuel supply was maintained at such a rate so that temperature of water content reaches more than 95°C before the marginal cooking takes place and once the temperature reaches 95°C then the fuel supply was terminated. Then the system was allowed not to be disturbed and cooking gets completed in its own heat. In this type of cooking art, cooking gets initiated from the uppermost layer and proceeds towards the bottommost layer. This novel heat transfer phenomenon gives a breakthrough in the cooking sector through energy and

time conversation points of view.

Designing aspects of Energy and Time Efficient Cooking Device

In some cases of cooking even though the heat supply rate is higher, it is found that the temperature inside the bed of food grains rises slowly and did not reach the cooking temperature within the stipulated period of time and hence dal or rice remains uncooked or partially cooked in the bottommost region of the vessel. Therefore the first design aspect is to heat up the water trapped inside the voids of bed as in a short time as possible. As shown in figure 4, the new cooking vessel has been designed to serve the above mentioned purpose. It consists of three portions; A, B and C. Portion A is located below the perforated plate and it covers the torispherical section of the vessel and contains only free water. Portion B is located above the perforated plate and it consists of the bed of food grains (rice or dal) and water inside of its voids, while portion C is located above the bed and it consists of free water only. Entire wall surface area of portion A and C is going to utilize for heat transfer and heat transfer process gets controlled through convective mechanism, while the wall surface area of portion B is not going to utilize for heat transfer entirely due to the presence of food grains (dal or rice). The convective currents going to develop inside the bed gets disturbed due to the presence of food grains. Therefore heat transfer rate is higher in portion A and C rather than portion B. Therefore water existing in portion A and C gets heated up earlier than the water exists in portion B. As the water available in portion A gets heated up then its density reduces and it rises up, it means convective currents get start to develop. These convective currents enter inside the voids of bed and at the same time, relatively cold water starts to flow downward for taking the place of uplifted water. This movement of water takes place through the perforated plate. In such a way, the water trapped inside the voids of bed gets heated up as in a minimum time as possible.

The base vessel is constructed of dished type or of torispherical types as shown in figure 4. Therefore the wall surface area at the base of the vessel increases and steam gets condensed at the vessel base effectively. The second scientific benefit behind the construction of vessel base as of torispherical or dished type is that water flowing down through the perforated plate tries to accumulate towards the centre of the base. Therefore water movement can be maintained inside the base of the vessel. Here heat transfer coefficient increases and the rate of heat transfer also increases. As the base is of torispherical or of dished type then water hold up inside the portion A increases and as a result, temperature gradient can be maintained for a long time and hence the rate of heat transfer increases. Therefore, water available in the base of the vessel gets heated up at a faster rate and that heated water rises up and enters inside the bed of food grains. As convective currents going to develop the movement of water inside the vessel can be maintained and hence the side wall heat transfer coefficient also increases. Therefore the overall rate of steam condensation increases.

Second aspect of the design is to increase the overall rate of steam condensation by increasing the area of heat transfer. The rate of heat transfer is given by $Q = hA\Delta T$, where, h is the heat transfer coefficient, A is the area of heat transfer and ΔT is the temperature gradient⁸. The heat transfer area can be increased by constructing vessels of smaller sizes rather than one bigger size. Therefore, three smaller vessels of having cumulative volume as same of the one bigger size have been constructed. These vessels are placed in a triangular pitch in the same horizontal plane as shown in figure 5.

Clearance has been also maintained between the vessels so that steam can get circulate around the perimeter of vessels easily. These vessels are held together in a stack with the support of central pipe. These vessel stacks are placed one upon another as shown in figure 6. The space is maintained between each of the stack, so that steam gets circulated through an angle of 360°. Each vessel in every stack is covered by a lid and it can withstand the load of upper vessel stacks. These

vessel stacks are supported by a supporting stand as shown in figure 6. The base of the supporting stand is of perforated type of plate, where in perforated section acts as a steam vent. The outer edge of perforated plate is curved in the downward direction so that the void space can be maintained between the base of cooker and the perforated plate. This void space is occupied by water and water level is maintained below the base of the bottom most vessel stack, so that, heat transfer takes place effectively by steam condensation. If the vertical pipe of supporting stand is hollow then the holes are made around its perimeter along its height. Therefore, steam can get circulate throughout the cooker easily without forming any dead zone.

Third aspect of the designing is to increase the rate of steam condensation by increasing the temperature gradient between the steam and vessel contents. The temperature gradient can be increased by forming the steam of high pressure and high temperature. High pressure steam is generated by boiling the water taken inside the basal receptacle. Trapped steam inside the cooker device increases boiling point of water. As the steaming chamber is sealed, the steam cannot get escape to the surrounding continuously. Therefore, pressure gets develop inside the cooker and boiling point of water increases. As the cooking device operates above the atmospheric pressure, the steaming chamber has been designed through a special art. It comprises a basal receptacle and a heat insulated hollow air jacket. Basal receptacle and heat insulated hollow air jacket are firmly attached with each other in such a way that steam cannot get escape to the surrounding and can be separated easily from each other after the cooking process gets over. Basal receptacle is shaped to hold water and accommodate the bottom most vessel stack up to certain height as shown in figure 7. The hollow air jacket has been also shown in figure 7. It consists of an inner and outer wall and hollow space is occupied by air. Provision is made to fill the air inside the hollow space of the jacket up to certain pressure. As the heating is in progress, the air occupied inside the hollow space develops pressure in between the pressure inside the cooking device and open atmosphere. Occupied air inside the hollow space creates an intermediate atmosphere between the inside part of the cooker and open atmosphere. As the cooking device operates under high pressure (Approximately 2 bar and having the boiling point of water 120 °C), then the total pressure inside the cooker is the summation of vapor pressure (2 bar) and air pressure of one bar. Therefore the total pressure inside the cooker is quite more than bar. If the pressure of air inside the hollow space is increased up to 2 bar, then the gauge pressure that inner wall can withstand is of one bar. Similarly, the gauge pressure that outer wall can withstand is also of one bar. These two pressure differences are smaller than the direct pressure difference of two bar between inside of the cooking device and open atmosphere. The inner and outer walls of the jacket having the smaller thickness are capable for balancing the pressure difference between inside of the cooker and open atmosphere. Another benefit of hollow air jacket is that air acts as insulation and resistance to heat losses occurring to the surrounding, while heating is in progress and also maintains temperature inside the cooker for longer time even after terminating the fuel supply and hence the cooking gets completed in its own heat. The pressure relief valve is located on the inner wall of the jacket to maintain the pressure inside the cooking device below the designed safety limit.

As the cooking device operates at higher pressure then steam is not going to be lost to the surroundings continuously. Therefore water level inside the basal receptacle can be maintained and possibility of getting dryness has been avoided completely. Therefore the probability of burning the base of basal receptacle has been reduced drastically.

Experimental Validation

Cooking device which was designed on the basis of observed novel heat transfer phenomena has been shown in figure 7. It consists of vessel stacks which are placed one upon another. Each vessel stack consists of a set of three vessels

placed in a triangular pitch. These vessel stacks are held together by a supporting stand and enclosed by a steaming chamber. Steaming chamber consists of a basal receptacle and a double walled hollow air jacket. Air occupied inside the hollow space of the jacket balances the pressure difference between inside of the cooker and open atmosphere. It also acts as an insulation and avoids the heat losses taking place to the surrounding while cooking process is in progress. Therefore, the temperature inside the vessel contents is maintained for a long time even after terminating the fuel supply and cooking takes place in its own heat. Two kg of water was taken into the base of basal receptacle. Perforated plates were placed in each of the vessel on its Torispherical portion. One kg of rice and 2.5 kg of water were taken into each of the vessels. The extra quantity of water to occupy Torispherical volume was also added to each of the vessels. LPG gas was used as a fuel and it was supplied at the rate of 16 gm/min for 25 minutes and then after it was terminated. While the heating was in progress, water taken into the base of basal receptacle boils, forms steam and these formed steam travels upward and condenses on the outer wall of vessels to transfer latent heat to the vessel contents. Once the fuel supply was terminated then the system was allowed not to disturb and cooking was allowed to complete in its own heat. Once the cooking gets completed, the steam which was trapped inside the cooking device was released through the pressure relief valve and the system was turned back to the normal conditions. The total quantity of LPG gas of 400 gms was utilized for the cooking of 9 kg of rice. The LPG gas consumption is about 1400 - 1500 gm to cook the same quantity of rice in open pot cooking system. The time required for the complete cooking of 9 kg of rice in the newly designed cooking device was of 55 minutes while in open pan cooking system it takes nearly about 80 minutes. Open pan cooking system has been shown in figure 8. Therefore, time efficient cooking was carried out in the newly designed cooking device with 70-80% of fuel saving as compared to the open pot cooking system.

Fuel economy of an open pot cooking system depends upon the geometry of cooking vessel and the rate of fuel supply. As the diameter of cooking vessel decreases then the thickness of rice bed increases and convective currents going to develop inside the food bed gets disturb which has a negative impact on fuel economy. Secondly, the heat released from the combustion of supplied fuel is not going to absorb completely by vessel contents. As the rate of fuel supply increases then the rate of heat release through the combustion also increases. Therefore, the heat absorption rate increases and proportionally heat losses taking place also increases and fuel economy gets reduced.

Significance of the Research and Invented Technology

Environmental and Health Impact

Asian countries are highly populated with higher population density. Daily consumption of food in hospitality industries in such countries is very high. In hospitality industrial sector located in metropolitan cities, generally a single restaurant or hotel etc prepares the meal of more than 100 peoples per day. Rice and dal is mostly preferred food in the Indian subcontinent. These sectors practice open pan system for the cooking of rice and dal on such a large scale. As the food intake of Indian people is considered, on an average 9 kg of raw rice has to cook for preparing the meal of 100 people and it has been estimated on the basis of Indian calories taken per person. From the experimental data of cooking it is observed that with open pan cooking system almost 1400 gm of LPG gets consumed for the cooking of 9 kg of raw rice in nearly about 80 minutes. Due to high cost of land per sq.foot and scarcity of the place in metropolitan cities like Mumbai, kitchen size is restricted to a small size on an average having the space of 300-400 sq.foot. In such a small space it is necessary to predict the level of build up concentration of carbon dioxide going to form from the combustion of fuel used in cooking process. The volume of the entire kitchen may vary from case to case but on average it will be in the range of 6000 cubic feet occu-

pying the air of 170 kg as per the standard atmospheric conditions. As discussed earlier, in an open pan cooking system 1400 gm of LPG gas has to burn in 80 minutes for carrying out complete cooking of 9 kg of raw rice. Therefore, the resulting rate of LPG supply is about 16 gm/min and has a composition of about 60% of propane and 40% of butane. Some particulate matters (PM), CO₂, CO, SO₂, NO and NO₂ forms from the combustion of LPG ¹¹. The releasing rate of carbon dioxide from the combustion of LPG is almost 52.75 gm/min. If the ventilation is not proper then it starts to accumulate inside the confined space of kitchen and its concentration starts to build up as combustion gets continue over the period of time. The effect of the concentration of carbon dioxide and carbon monoxide on climate conditions and human beings has been noted down in Table 2 and 3 respectively ¹⁰. The total quantity of carbon dioxide released from the combustion of LPG of 1400 gm supplied over the period of 80 minutes is about 4-5 kg and therefore it is a challenging task to maintain the concentration of carbon dioxide below 2000 ppm every time if the ventilation is not proper. These are the regular challenges that need to be faced for carrying out cooking on a large scale in an open pan cooking system. By taking into the consideration above mentioned aspects of pollution, energy and time, an innovative cooking device has been invented and it is found that it consumes only about 400 gm of LPG to cook the same quantity of rice. Therefore the fuel saving in an invented cooking device is up to 70 % as compared to open pan cooking system. Another benefit is that there is 70 % reduction in carbon dioxide formation which helps to control the concentration of carbon dioxide in confined space below 2000 ppm. The monthly average consumption of LPG for cooking purposes in the Indian context per household was 11.8 kg in 2004-05 and 11.7 kg in 2009-10 ¹². Therefore, daily consumption of LPG per household is in the range of 0.4-0.5 kg for the preparation of food of both times means 0.25 kg for a single time. By knowing this daily basis consumption of LPG for household cooking purposes and the resulting concentration of different pollutants built-up inside the confined space of household kitchen ¹¹, the concentration of same pollutants going to build up inside the confined space of hospitality kitchen has been predicted and noted down in Table 4. Combustion time of LPG in an invented cooking device is about 25 minutes while in open pan cooking system it is about 80 minutes which means that the invented cooking device reduces the exposure time to the intense carbon dioxide forming atmosphere drastically as per the residence time distribution.

Economical Impact

LPG is considered as a clean fuel compared to solid biomass fuel and therefore the government of India has taken initiative to promote usage of LPG for cooking purposes throughout the country including rural areas. The Government of India is providing free gas (LPG) connections to poor people under Pradhan Mantri Ujjwala Yojana (PMYU). Therefore, India becomes the world's 2nd largest consumer of LPG after China. Due to rapid growth in population and penetration of LPG in rural areas, India made the record of 22.5 million tons of LPG consumption by 2018 and it is expected to grow to 30.3 million tons by 2025 and 40.6 million tons by 2040 ¹³. The LPG consumption per annum and the growth rate in the consumption in India has been shown in Figure 9 and 10 respectively. As per the current scenario, total annual energy consumption for cooking purpose in India is about 4E+12 MJ and LPG contribution about 32% ¹⁴. In the present situation, the price of LPG in Indian context is about 60 INR per kg ¹⁵ and consumption of LPG in the year of 2020 is about 27.4 million tons ¹⁶ which costs about 1.492 Trillion rupees. Cooking with the innovative cooking device saves about 70% of fuel and therefore there is a prediction of net reduction in the cost by 70%.

CONCLUSIONS

Cooking is a very ancient phenomenon which was known to human being even during the early stages of evolution. Till the present time, it was considered that in cooking phenomenon as the heat gets supplied externally to the cooking device

the temperature increases inside the cooking device and eventually cooking goes in progress. But in this newly invented next generation's energy and time saving cooking device this phenomenon of cooking is distinctly different in which temperature inside the cooking vessels rises even after terminating the fuel supply. It is also observed that, once the local temperature inside the vessel contents reaches more than 85 °C for rice and 95 °C for lentils, then there is no need for further heat supply and cooking gets complete in its own heat. In this art, cooking gets initiated from the uppermost layer and precedes towards the bottom most layer. On the basis of the observed novel heat transfer phenomena, a cooking device capable of carrying out time efficient cooking with 70% of fuel saving compared to the open pan cooking practice has been designed, fabricated and commences. Heat Transfer process occurring inside the vessel of cooking device which is designed in this art has been controlled completely through convective mechanism. It is also useful for carrying out uniform cooking on a large scale also. Such types of innovative cooking practice has a significant impact on energy and time conservation as far as the cooking sector is considered.

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AUTHOR CONTRIBUTIONS

S.G.Shingade and P.D.Gangawane conceived and designed the experiments. S.G.Shingade designed the time and energy efficient cooking device. S.G.Shingade and P.D.Gangawane validated the cooking experiments on newly designed cooking device and compared with open pan cooking system. S.G.Shingade and P.D.Gangawane co-wrote the paper. All authors discussed the results and commented on the manuscript.

Competing Interests

The authors declare no competing financial interests.

Figure 1 | Cooking appartas operating at 1 atm pressure.

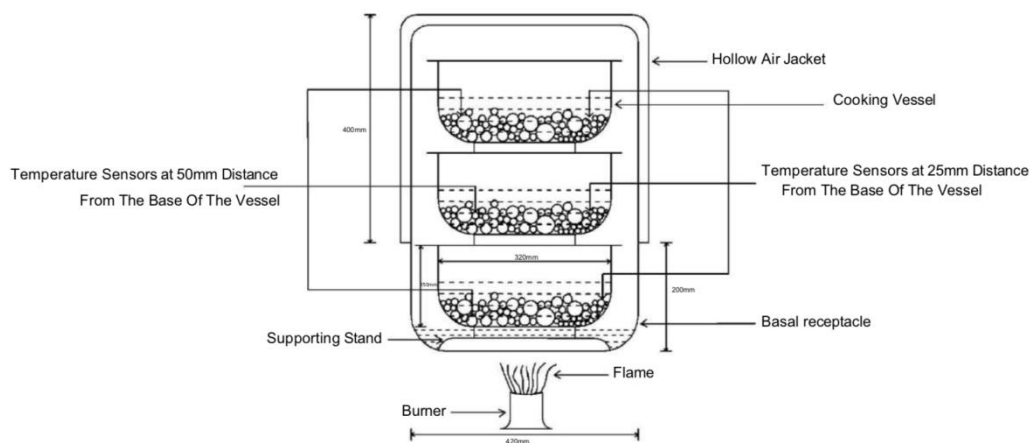


Figure 2 | Normal cooking vessel.

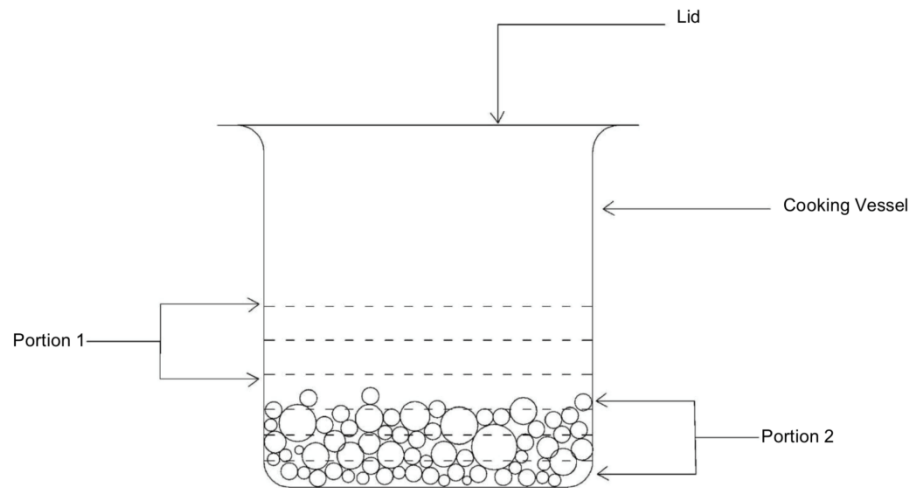


Figure 3: Temperature Profile Inside the Cooking Vess

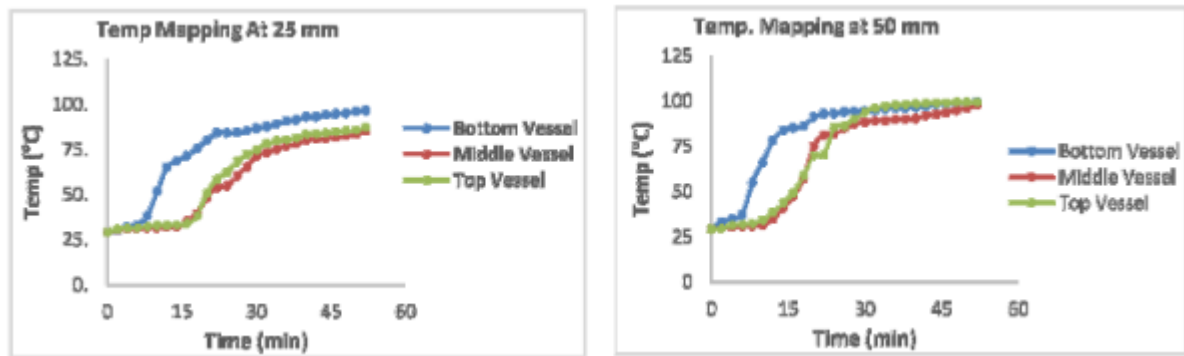


Figure 4 | Cooking vessel of energy and time efficient cooking device.

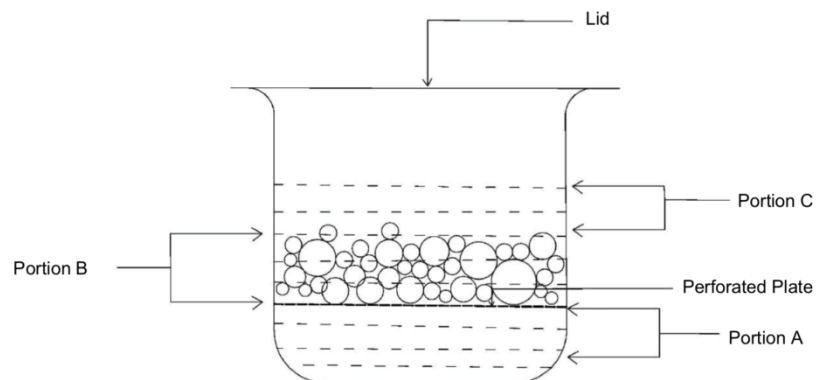


Figure 5 | Vessel stack.

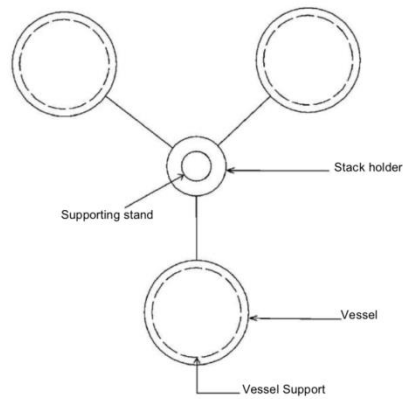


Figure 6 | Vessel stack assembly.

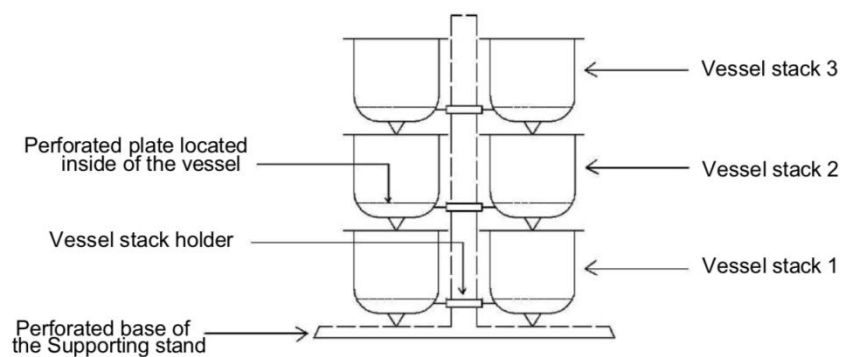


Figure 7 | Energy and time efficient cooking device with dimensions.

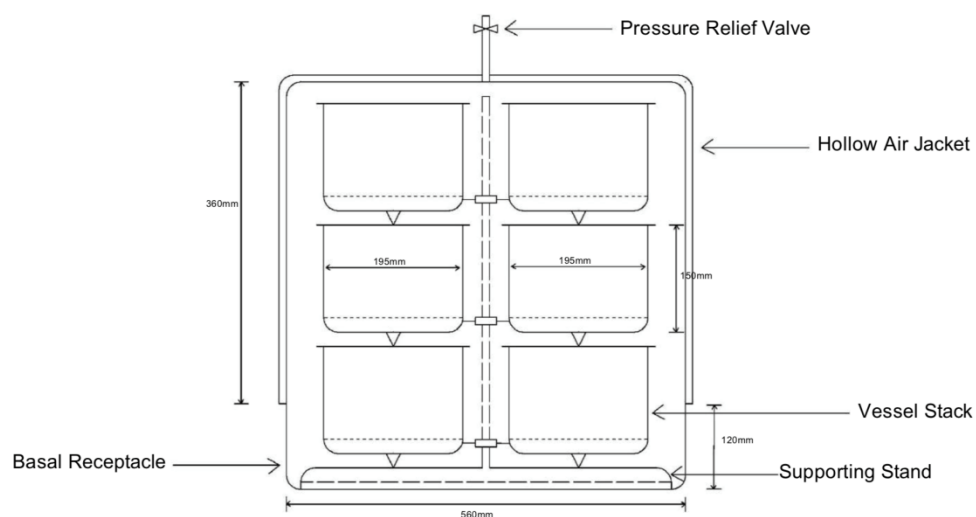


Figure 8 | Open pan cooking system with dimensions.

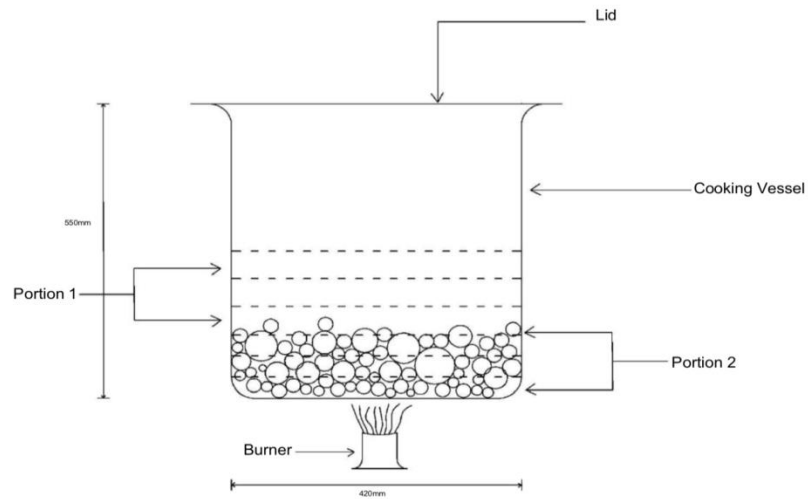


Figure 9 | LPG Consumption per annum in Indian context.

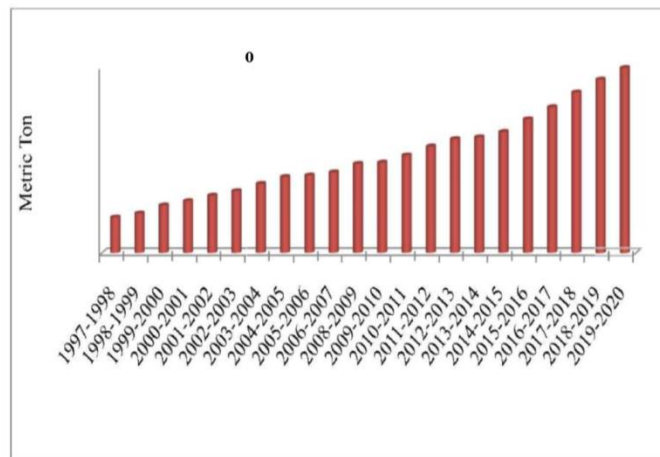


Figure 10 | % Growth in LPG consumption per annum in Indian context.

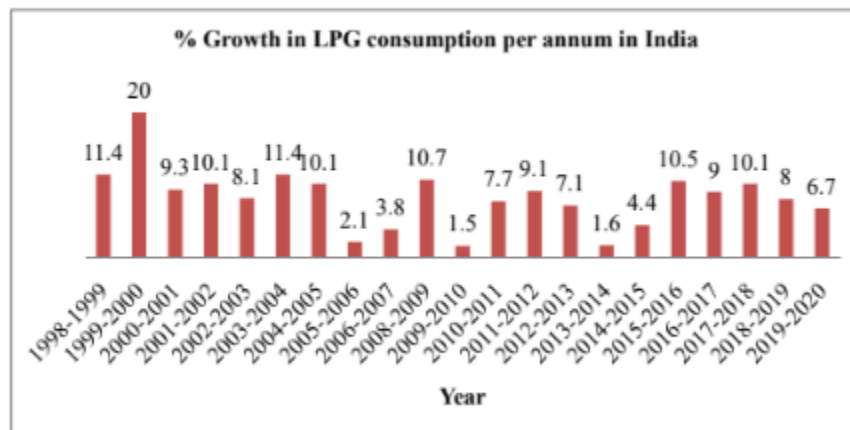


Table 1 | Temperature mapping inside the cooking vessels.

Sr. No.	Time (min.)	Distance of the Temperature sensor from the bottom of the vessel.					
		25 mm			50 mm		
		Bottom Vessel	Middle Vessel	Top Vessel	Bottom Vessel	Middle Vessel	Top Vessel
1	0	29.3	29.3	29.3	29.3	29.3	29.3
2	2	30.1	30.5	30.8	33.2	30.1	29.9
3	4	32	31	31.2	35	30.7	31.5
4	6	33.3	31.2	31.8	37.2	30.9	31.7
5	8	38	31.6	32.2	55	31	32
6	10	51.5	31.7	32.5	66	31.7	34.2
7	12	65.1	31.9	32.7	78	34.8	38.1
8	14	68.5	32	33	83.5	41	43.5
9	16	71.4	35	34.1	85	47.5	49
10	18	75.3	39.2	38.2	86.2	57.1	58.5
11	20	80	48.2	50.2	91.2	74.8	70
12	22	84.1	54.1	58.2	93	81.2	70.2
13	24	84.2	54.5	62.1	93.1	81.8	85.1
14	26	84.4	60	68	94	85	86.2
15	28	85	65.2	72	94.2	87.2	90

Table 2 | Effects of carbon dioxide on indoor climate conditions.

CO ₂ Concentration	Effect of CO ₂ on climate and human health
250-400ppm	Normal concentration level of CO ₂ in outdoor ambient air
400-1,000ppm	Indoor spaces with good air exchange
1,000-2,000ppm	Causes the complaints of drowsiness and considered as poor air quality.
2,000-5,000 ppm	Causes the health related problems like headaches, sleepiness and stagnant, poor concentration, loss of attention, increased heart rate and slight nausea.
5,000 ppm	Accepted workplace exposure limit in most jurisdictions.
>40,000 ppm	Exposure may lead to serious oxygen deficiency resulting in permanent brain damage, coma and even death.

Table 3| Effects of carbon monoxide on indoor climate conditions.

CO Concentration	Effect of CO on climate and human health
9 ppm	Maximum prolonged exposure to CO
35 ppm	Maximum exposure to CO for 8 hour work day
800 ppm	Can cause death within 2 to 3 hours
12,800 ppm	Can cause death within 1 to 3 minutes

Table 4 | Concentration of pollutants inside of the kitchen room resulting from the combustion of LPG

Pollutants releasing through the combustion of LPG	Concentration of pollutants in household kitchen	Predicted concentration of pollutants in hospitality kitchen practisizing open pan system for the cooking of 9 kg of raw rice	Predicted concentration of pollutants going to develop in hospitality kitchen practisizing if they practicize invented cooking device for the cooking of 9 kg of raw rice
SPM	114.73 $\mu\text{g}/\text{m}_3$	642.488 $\mu\text{g}/\text{m}_3$	183.568 $\mu\text{g}/\text{m}_3$
CO	1.34 ppm	7.504 ppm	2.144 ppm
CO₂	379.83 ppm	2127.048 ppm	607.728 ppm
SO₂	0.52 ppm	2.912 ppm	0.832 ppm
NO	0.54 ppm	3.024 ppm	0.864 ppm
NO₂	0.52 ppm	2.912 ppm	0.832 ppm

